Physics 1320
Exam 2
MONDAY, APRIL 13, 2020

Directions:

The start time for this exam is 10:00 am. You must scan your answers (with CamScanner) and upload them to "Learn" by 11:59 am - so you have an extra hour beyond the normal class time. Your answers can be written down on a piece of notebook paper, but **please put your name on the it**. Just as with homework submissions to "Learn", you may upload your answers multiple times; the "Learn" software will only retain your last upload. This exam is closed-book/notes, except for the formulae I have provided below. You are not to consult with the computer, or with others. I will be grading your exams individually, so please indicate your answers clearly.

Show your work for every problem. For numerical questions, your answers will only be marked as being correct if **three** *things are satisfied simultaneously.* First, the work you do to arrive at your answer must be appropriate/correct. Second, your work must logically lead to the answer you record; you won't be given credit if your work leads to one answer but you record a different answer. Third, your answer must the correct one. Obviously some problems requre more work than others.

The point-values of each question are indicated. The last problem is a 5 point bonus.

Useful information:
mass of proton 1.67×10^{-27} kg
mass of electron 9.1×10^{-31} kg
$\frac{1}{4\pi\epsilon_0} = 9 \times 10^9$ Nm^2/C^2
proton's charge 1.6×10^{-19} C
electron's charge -1.6×10^{-19} C
The prefix n means "nano", and stands for a factor of 10^{-9}
$\oint \vec{E}\cdot d\vec{A} = \frac{q_{enclosed}}{\epsilon_0}$

(1-5pts) An 0.5 A current passes through a 4.0 Ω resistor. At what rate is energy dissipated as heat in the resistor?
(a) 1.0 W
(b) 2.0 W
(c) 3.0 W
(d) 4.0 W
(e) 5.0 W

(2-5pts) If a 2.0 mA current in a resistor is due to the movement of electrons, on average, how many *electrons per second* pass across the resistor?
(a) 0.25×10^{16} per second
(b) 0.50×10^{16} per second
(c) 0.75×10^{16} per second
(d) 1.00×10^{16} per second
(e) 1.25×10^{16} per second

(3-5pts) A 20 mA current is due to the drift of holes in a leaky parallel plate capacitor. If the plate area is 0.035 m^2, what is the current density?
(a) 0.33 A/m^2
(b) 0.57 A/m^2
(c) 0.74 A/m^2
(d) 0.94 A/m^2
(e) 1.11 A/m^2

(4-5pts) The density of free charges in a leaky capacitor is 1.25×10^{21} per cubic meter. If the current density is 1.00 A/m^2, what is their drift velocity?

(a) 1.00×10^{-2} m/s
(b) 2.00×10^{-6} m/s
(c) 3.00×10^{-5} m/s
(d) 4.00×10^{-4} m/s
(e) 5.00×10^{-3} m/s

(5-5pts) A parallel plate capacitor has a plate area of 30 m^2 and a gap of 20 μm. How much charge is required to bring it to a potential of 1.5 V? Assume that the dielectric constant is 3.0.

(a) 20 μC
(b) 30 μC
(c) 40 μC
(d) 50 μC
(e) 60 μC

(6-5pts) What is the minimum work required to charge up an *isolated* metal sphere of radius 10 cm to 10 nC in free space?

(a) 2.5 μJ.
(b) 4.5 μJ.
(c) 5.5 μJ.
(d) 6.5 μJ.
(e) 8.5 μJ.

(7-5pts) A spherical shell of radius 10 cm is uniformly charged so that charge density on the surface is 1.00 nC/m^2. At the center of the shell is a point charge of -0.126 nC. What is the magnitude of the electric field at a point *outside* the shell at a radial distance 15 cm from the center?

(a) 454 N/C
(b) 345 N/C
(c) 280 N/C
(d) 151 N/C
(e) 0 N/C

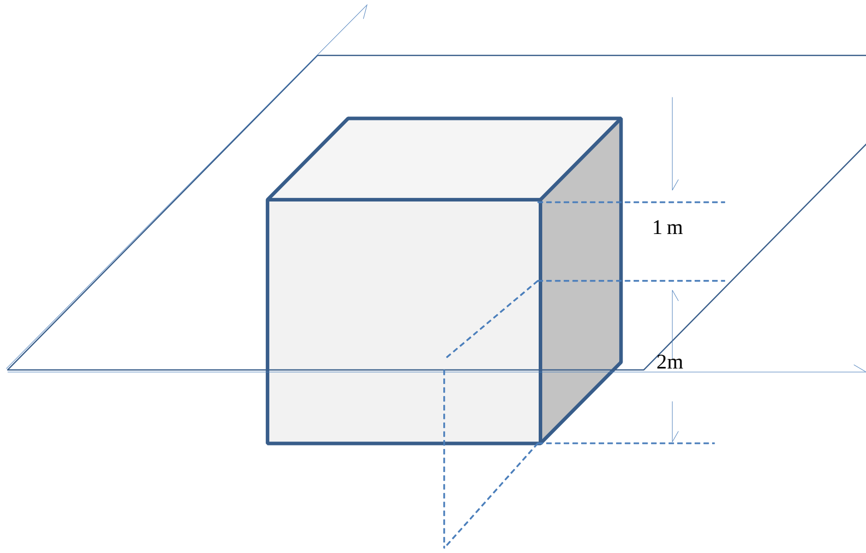
(8-5pts) The electric field strength is 3×10^6 N/C at a point just above the head of a metal golf club. What is the surface charge density on the head at this location?

(a) 0.5 μC/m^2
(b) 6.5 μC/m^2
(c) 12.5 μC/m^2
(d) 21.5 μC/m^2
(e) 26.5 μC/m^2

(9-5pts) Consider two surfaces with the geometry of a parallel plate capacitor with surface area 0.01 m^2 and a gap of 10 μm. If *both* surfaces have a *positive* uniform charge density of 3.0 nC/m^2, what is the electric field strength outside the capacitor, just above the top surface (or just below the bottom surface)?

(a) 339 N/C
(b) 344 N/C
(c) 475 N/C
(d) 513 N/C
(e) 610 N/C

(10-5pts) An infinite plane in the xy plane has a surface charge density $\sigma = 5$ nC/m^2. Consider an imaginary "Gaussian surface", a 3m$\times$3m$\times$3m cube, with top and bottom faces parallel to the xy plane. The top face is 1 m above the plane. The bottom face is 2 m below the plane.



What is the electric flux $\phi = \oint \vec{E} \cdot d\vec{A}$ integrated over all six faces of the cube?

(a) $\phi = 0$ Nm^2/C
(b) $\phi = 1225$ Nm^2/C
(c) $\phi = 2545$ Nm^2/C
(d) $\phi = 3465$ Nm^2/C
(e) $\phi = 5089$ Nm^2/C

(11-5pts) Two point charges are positioned along the x axis. A charge of 1.0 nC is positioned at $x = -1.0$ m, and a charge of -4.0 nC is positioned at $x = 1.0$ m. What is the net force on a third -1.0 C point charge at $x = -3.0$ m?

(a) -2.5 N $\hat{\imath}$
(b) -3.8 N $\hat{\imath}$
(c) -7.3 N $\hat{\imath}$
(d) $+8.5$ N $\hat{\imath}$
(e) $+5.5$ N $\hat{\imath}$

(12-5pts) An electron and a hole are separated from one another by 1.0 Å. What is the dipole moment of this charge configuration in Debyes? (1 D $\simeq$ 0.2 eÅ, and 1Å=0.1 nm)

(a) 1 D
(b) 5 D
(c) 7 D
(d) 9 D
(e) 10 D

(13-5pts) Which of the following is true?

(a) The electric field at the surface of a conductor in equilibrium must be parallel to the surface.
(b) In equilibrium, all points on a conductor are at the same potential.
(c) Charges placed on a conductor will distribute in a manner that maximizes the free energy.
(d) The electric field inside of a charged conductor (beneath the surface) is the same as it is outside (just above the surface).
(e) A metal conductor can only be given a negative excess charge.

(14-5pts) A 2μF capacitor is charged to 3μC. The capacitor is made of two concentric metal spherical shells. The space between the two shells is empty - a vacuum. The inner shell is negative, and the outer shell is positive. If an electron escapes from the inner shell, how fast will it be moving when it strikes the outer shell if it starts from rest? (Note: 1 eV = 1.6$\times$10^{-19} J)

(a) 7.3×10^5 m/s.

(b) 5.3×10^4 m/s.

(15-5pts) The spacer in a parallel-plate resistor (a leaky parallel plate capacitor) with plate area 1.0×10^{-1} m^2 and gap 2.0×10^{-3} m has a resistivity of $3.0{\times}10^3$ Ωm. What is the resistance of the resistor (in Ω)?

(a) 30
(b) 40
(c) 50
(d) 60
(e) 70

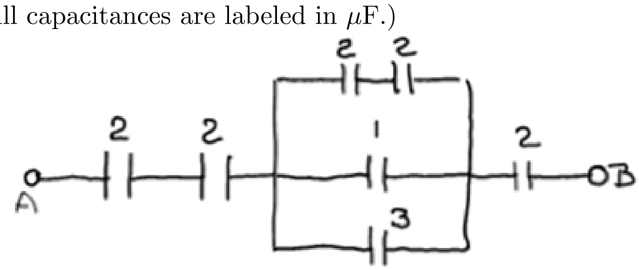
(16-5pts) The distance between the electron and the proton in the hydrogen atom in its ground state is $0.529{\times}10^{-10}$ m. For this separation, the electrical potential energy is -27.2 eV. What is the change in electrical potential energy if the the distance between the electron and proton doubles? (Note: 1 eV = $1.6{\times}10^{-19}$ J)

(a) 13.6 eV
(b) 14.8 eV
(c) 16.2 eV
(d) 18.8 eV
(e) 20.4 eV

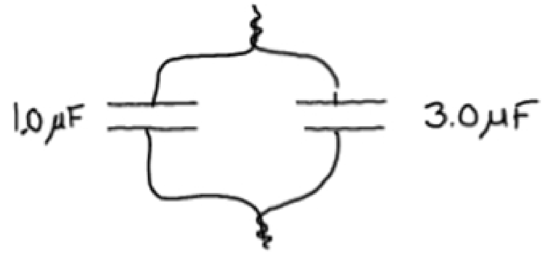
(17-5pts) A resistor carries a current of 1.0 mA. If the potential drop across the resistor is 5 V, what is the resistor's resistance in kΩ?

(a) 3.0 kΩ
(b) 4.0 kΩ
(c) 5.0 kΩ
(d) 6.0 kΩ
(e) 7.0 kΩ

(18-10 pts) What is the equivalent capacitance between points A and B for the configuration shown below. (All capacitances are labeled in μF.)



(19-5 pts) A capacitor C_1 =1.0 μF is charged to 10.0 Volts in equilibrium. It is connected in a closed-loop circuit to a second capacitor C_2 =3.0 μF that is initially uncharged, at which point charge spontaneously flows from C_1 to C_2. What will be the voltage across each capacitor when equilibrium is reestablished?



(20-Bonus: 5pts)

For problem 19 above, what is the maximum work that could be extracted from the process were one so inclined?